Black Holes

Summary:

Students are introduced to the basic properties and behavior of black holes through a brief discussion, including how it might be possible to detect black holes through their interaction with other stars. Then they "act out" binary star systems in pairs, walking slowly around one another in a darkened room with each pair holding loops of wire to simulate the gravitational interaction. Most of the students are wearing glow-in-the-dark headbands to simulate stars. Some are not wearing headbands and represent black holes. A small set of the black holes have flashlights to simulate X-ray emission.

Purpose:

To teach some of the properties of black holes and how they interact with normal stars.

Audience:

~ 20 students (grade range 6^{th}-9^{th}) in a group works well

Objectives:

1. Explain the basic properties of black holes including
    a. Escape velocity
    b. Gravitational interactions
    c. Accretion disks
2. Demystify black holes
3. Brainstorm with students ways they might observe objects or phenomena which they cannot see directly
4. Introduce basic X-ray physics

Materials:

- 1 tennis ball
- 5-6 loops of heavy gauge wire, ~ 36 inches in circumference
- 5-6 loops of heavy gauge wire, ~ 60 inches in circumference
- paper headbands (1 per student)
- glow-in-the-dark stickers and/or decorations
- tape or stapler
- 6 flashlights and batteries
- red cellophane to cover flashlight lenses
- tissue paper party decorations – 2 large (~ 8 inch diameter) balls, 1 large (~ 24 inch diameter) disk

- room with adequate space to move around for the activity
- completely blacked-out room (optional)

Kit and Room Preparation:

1. Wire loops: ~ 10 minutes

   Cut and shape the wire into 5-6 medium sized loops (~ 36 inches in circumference) and 5-6 large loops (~ 60 inches in circumference)

2. Decorate the headbands (this can be done in advance or with the students): ~ 10 minutes

3. Darken the room: ~ 10 minutes

   The room should be capable of going from brightly lit to dark so that the glow-in-the-dark headbands can be seen effectively. Sometimes this means lights or light leaks must be covered. Dark black plastic trash bags and duct tape have proved useful for this.

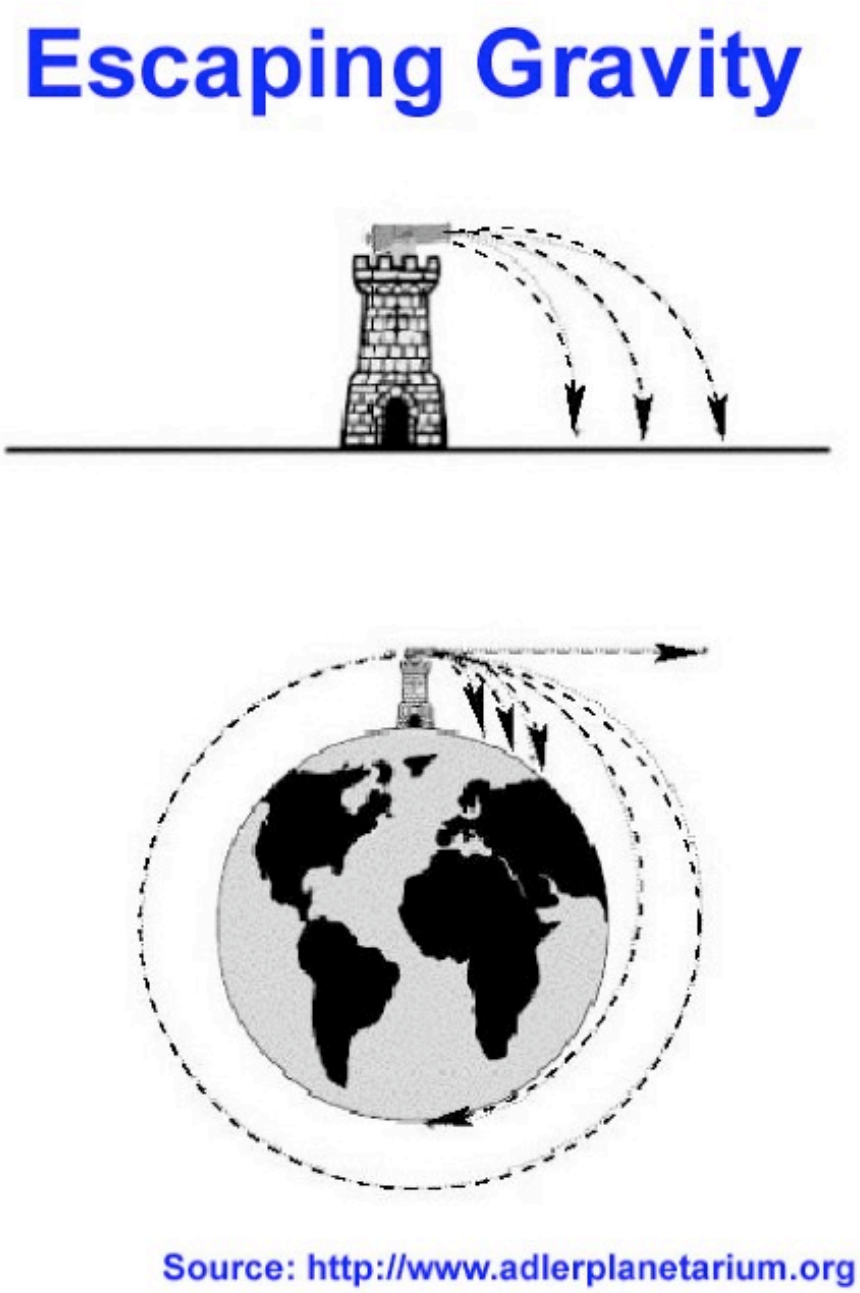
Activity Procedure and Discussion:

This activity can be completed in 45 minutes. A sample script and flow of discussion follows.

Part I: What is a Black Hole? (~ 10 minutes)

The leader explains Black Holes (BH's) based on the following points:

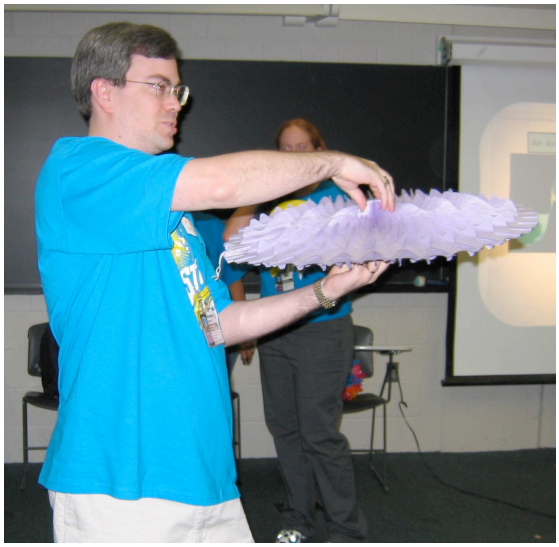
1. What is a BH? Explain concept of escape speed considering a tennis ball on earth (how hard must I throw this ball for it to go into orbit (and what does it mean to "orbit"? Now if I am on the moon, how hard must I throw to get the ball into orbit around the moon?). [Use image of a cannon on a very tall tower to help illustrate how throwing something harder could put it into orbit.] Then explain BH by explaining that the escape speed from a BH is greater than the velocity of light and therefore nothing (not even light) can escape from inside a BH.



2. Concept of an orbit: Earth and the other planets orbit the Sun; two stars orbiting each other are known as binary stars. (Helpers can demonstrate orbiting stars using big balls or one of the wire loops used for the activity.) Point out that roughly half of the stars visible in the sky are binary stars, so it is relatively common.

3. How would you observe a BH? After all, if even light cannot escape a BH, how can they been 'seen'? Explain that BH's are observed by the effect of gravity, i.e. by observing stars and other materials apparently orbiting around nothing that can be seen. [This can be demonstrated by the leader explaining "If I were a BH and I was close to a normal star, say you (standing close to one of the students), what do you think the effect would be?]

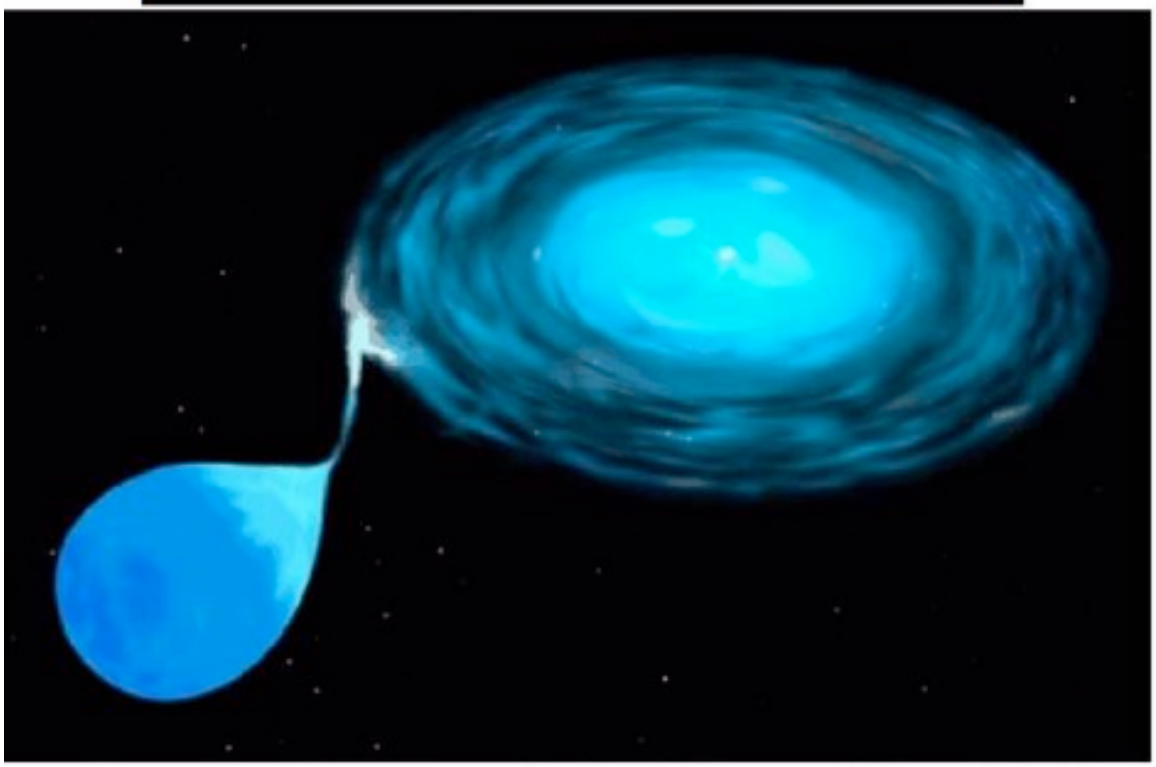
4. Explain accretion disks: materials spiraling in (why does it spiral?) and light emitted by that heated material (why is it heated? answer: friction) is observed by us. Explain that a lot of such light emitted close to the BH is in X-rays and why. Demonstrate what this looks like with the tissue paper disk and ball from the kit. [Use image of an artist's conception of an accreting black hole to help with the visualization of an accretion disk.]



Note:

If the students have already seen a movie describing black holes, it may be sufficient to discuss the above ideas only briefly and instead answer questions or discuss common misconceptions – i.e. black holes are NOT cosmic vacuum cleaners, time does NOT stop inside them, etc.

An Accreting Black Hole



Credit: Astronomy Picture of the Day
http://antwrp.gsfc.nasa.gov/apod

Part II: Activity (~ 20 minutes)

Explain the activity to them. Some of them are going to be normal stars, without a pair, moving through the galaxy (2 or 3 students), some of them are going to be normal binary star pairs (2 or 3 pairs) and some are going to be normal star & BH binaries (2 or 3 pairs) - the latter which will be observable only with their 'X-ray' eyes. Give all the normal stars a glow-in-the-dark headband and the BH's a flashlight. Give the binary star pairs a large loop of wire and the star/BH binary pairs a medium sized loop. The idea here is that with the closer binary systems, the star and BH are close enough for accretion to take place, i.e. the star "donates" some of its mass to the BH, and X-rays turn on. Practice once with the lights on what everyone is supposed to do. It is useful to have a helper stationed by the light switch who can make the room go dark at will. Make sure you tell them to move slowly in circles around each other or move slowly around the classroom (for the single stars) and reposition students as necessary to avoid collisions. The stars in binary systems with BH's must move much slower than normal binary stars. Then turn off the lights and first observe with 'normal' eyes (without flashlights being turned on). Then, say 'Turn on your X-ray eyes' and the BH's should turn on their flashlights at this time. Ask the students to observe both with 'normal' eyes and 'X-ray' eyes. After this turn lights back on. It may help to redistribute the flashlights so that more students can have a turn as a BH.

Part III: Wrap-up (~ 10 minutes)

Ask them questions based on this activity. An example is, how do you identify BH's? While the leader does this, the helpers should go around and collect the headbands, flashlights, and wire loops. Past experience indicates that this question-and-answer session doesn't always work.